Using Calculators in Mathematics Education[1] in Korean Elementary Schools

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Mathematics subject of the seventh national curriculum in Korea, which has been effective since 2000, strongly encourages the use of calculators and computers to help children gain a better understanding of basic mathematical concepts and develop creative thinking and problem-solving skills without spending too much time and effort on making mechanical computations. Despite the recommendation by the national curriculum, however, only a small segment of elementary school teachers have been using calculators because of the fear that children's dependence on calculators might bring about negative consequences. As a result, little research has been conducted in this area as well.

This study has been conducted on the assumption that calculators have the potential for being a useful instructional tool in certain areas of elementary school mathematics education. To investigate the usefulness of calculators, a review was made of the scanty literature in the area. The literature review indicates that calculators are effective when they are used for the following purposes: understanding concepts and properties in numbers and operations, deducing mathematical rules, and solving problems. In view of the available research findings, we will give some concrete learning and teaching models of such uses of calculators. The teaching-learning models are organized around three categories:

concept formation, discovery of principles and rules, and problem solving.

Such organization is intended to help teachers use the models with ease.

1. NEEDS FOR USING CALCULATORS

Mathematics subject of the seventh national curriculum recommends strongly the use

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of calculators and computers to help children develop understanding of mathematical concepts, improve problem-solving skills and develop creative thinking skills. The prevalent educational environment in which calculations are conducted using paper and pencil has led to a situation where there is little concern about utilizing calculators as a tool for mathematics education. As a result, research evidence about the proper role of calculators is scarce as well.

The mathematics education should focus more on teaching important mathematical concepts and principles than on developing mechanical calculating skills. In order to do this, it is essential that children spend more time and effort on learning those concepts and principles, while reducing those spent on mere calculations. This is why it is essential that we let children use calculators. In addition, most of us use calculators when we need to calculate in daily life. In this situation, adherence to a paper and pencil calculation is in conflict with the constructivistic principle, which states that learning takes place when it presupposes the learning experiences of the learner. This also highlights the need to use calculators in mathematics education. With the development of relevant technologies, teachers are requested to take advantage of technological advancements. As classrooms are being equipped with high-tech facilities such as computers and calculators, it is important that research be conducted on the relevant role of calculators in mathematics education.

It is generally agreed that technological developments can contribute to developing students' mathematical thinking processes and understanding. The use of technologies, however, often faces resistance from traditional learning and teaching environments as well as practicing teachers. With such situations in mind, this presentation studies the pros and cons of using calculators in Korean elementary schools, on the basis of research publications, which address various aspects of calculator use in elementary mathematics education.

This analysis is followed by a discussion of the types of questions where calculators can best be utilized. Then an instructional model is suggested to demonstrate an effective use of calculators in mathematics education.

2. PROS AND CONS OF USING CALCULATORS

About ten research studies have been conducted on the use of calculators in elementary schools in Korea in the past ten years. These include Lew (1991), Koo (1992), Whang (1994, 1996), Kim & Jung (1995), Park (1997, 1998), Nam & Kim (1998), Ahn & Kim (1998), and Ahn et al. (2000). A close analysis of these studies shows that calculators have the following advantages and disadvantages as an instructional tool.

1) Advantages

- The uses of calculators help students get a sense of numbers as well as facilitate the understanding of mathematical principles and concepts.
- By saving the time needed for calculation, the use of calculators leaves more time for conceptual understanding and problem solving.
- It helps students attain more learning in both scope and depth.
- It contributes to changing students' perceptions that mathematical learning involves just calculations.
- The uses of calculators help students better adjust themselves to society.
- Students who are limited in their calculation skills can get some help in dealing with numbers and solving problems.
- The uses of calculators help students get more interested in mathematics as well as enhancing their academic accomplishments.

2) Disadvantages

- It may reduce mathematical thinking skills.
- It may give a distorted impression of what the essence of mathematics is.
- It makes it difficult to pinch out where the pitfall is.
- Calculators are nothing more than an educational tool
- Many people are against the use of calculators.
- It could negatively affect the motivation to learn the basic arithmetic algorithm and its function.
- It tends to put more emphasis on the use of prime numbers than fractional numbers.
- It may distort the main current of elementary mathematics curriculum by putting more value on collecting, analyzing, processing materials as well as focusing teaching how to solve problems.

Research findings suggest that calculators are best used in higher grades in elementary schools. Specifically, grade 5 is regarded as the appropriate period to begin to use calculators (Park, 1998). In Japan and Britain, research evidence indicates that grades 3 and 4 may be the most proper time to introduce the use of calculators respectively (Shimizu, 1992; Kim & Jung, 1995). In the case of Korea, Lew (1991) proposes for revising the curriculum so that calculators can be used in higher grades in elementary schools.

These research results indicate that the use of calculators in mathematics classes is not desirable for children in grades 1 and 2. For those who are in grade 5 or above, the use of calculators is strongly recommended so that the time and effort thus saved can be used for

developing understanding of mathematical theories and concepts.

The mathematics education in Korea has been criticized for spending too much time and effort on the rote memorization of mathematics facts and algorithms without paying due attention to ways of solving problems. To address the situation, Koh (1999) claims that active inquiries and knowledge construction should be the mainstay of mathematics education.

3. PATTERNS OF CALCULATOR USE AND TEACHING-LEARNING MODELS

The calculator is an educational tool, which can improve the quality of learning and curriculum in mathematics conceptualization, inquiry of patterns, understanding of fundamental principles, and problem-solving processes. It is particularly advantageous in teaching the nature and composition of numbers, the four fundamental processes of arithmetic; addition, subtraction, multiplication and division, the relations between a fractional number and a prime number, finding a divisor and a multiple number, and problem-solving through inferences and trial and error processes. There is a situation in which the use of a calculator is desirable (Kang, 1998). The calculator is much more than a mere calculation tool. It can be very useful in teaching the principles and concepts of mathematics as well as problem-solving skills (Kang, 1998). By doing the repetitive and complicated calculations attendant upon learning concepts with calculators, teachers can help students learn relevant concepts more effectively (Na, 1999). Park (1988) claims that the use of calculator saves much time on problem-solving and, as a result, students will be able to focus more on understanding the problems, planning to solve them, and reflecting on them.

This study is conducted on the assumption that calculators can be used in the four fundamental processes (i.e., addition, subtraction, multiplication and division) of arithmetic. For the most efficient use of the calculator, three patterns of use are suggested; concept formation, finding principles, and problem solving.

Appropriate teaching and learning models that fit each model have been used in real classroom situations (see Gwangju National University of Education Elementary School, 1999, pp. 235–280).

1) Perceptions of numbers and types of concept formation

The proper perception of figures is an important element in understanding the meaning of numbers and their relations, features of calculation principles (e.g., the commutative

law, the associative law, the distributive law) relating to figures, and developing calculation skills. For example, children can discover the regularity in numbers by doing practices like counting forward and backward and skipping particular numbers. We can also improve the sense of figures by developing the values of figures on numbers. For example, we can develop the values of figures by deleting 4 from 5431. In addition, we can estimate an approximate value by questioning this:

78 times of which numbers is between 1000 and 1500.

We can discover the system and regularity of figures by applying it to a complicated calculation as well. For example, we can give an activity in which students are asked to get the smallest possible number by filling in the blanks □ □ □ × □ with 4, 6, 8, or 9.

The concept formation type can be used to help build mathematics concepts. This type is used to discover common characteristics and regularities and expand the denotation according to the connotation by applying the calculator in the stage of conceptualization.

The teaching-learning process (see Table 1 below) can serve such purpose.

Table 1. Teaching-learning activity for concept formation

Stage	Teaching & learning activity
Presentation of task	Presenting the denotation of a concept relevant to the task at hand Understanding the objectives and content of lesson
Presentation of ideas	Presenting concrete ideas and the denotation of adjacent concepts Gathering the denotations of concepts by sorting using calculators
Conceptualization	Discovering a common point by abstraction using calculators Deciding the connotation of concepts
Generalization	Expanding the denotation according to the connotation using calculators Inserting in the original concept by symbolization
Application	Utilization of concepts Applying to solve the task using calculators

2) Understanding the properties and principles of calculation

Using calculators helps develop the understanding of the properties and principles of calculations. For instance, finding numbers appropriate to □ and △ in □ + △ = 8 and □ = 8 − △ helps students learn the relationship between additions and subtractions. Finding numbers appropriate to ○ and □ in ○ × □ = 408 and ○ = 408 ÷ □ makes helps them get to know the relationship between multiplications and divisions.

Also, $3 + 3 + 3 + 3 + 3 = 3 \times 5$ confirms the relationship between additions and multiplications, and $12 - 4 - 4 - 4$ and $12 \div 4$ helps children understand the relationship between subtractions and divisions.

As seen, calculators can be used to help children gain understanding of the properties of four basic calculations. For example, the following questions ask students to make 1 through 6 by using four calculations.

$(5 + 5 \square 5) \div 5 = 1,$ $5 \div 5 \square 5 \square 5 = 2,$ $(5 \square 5 \square 5) \square 5 = 3,$
$(5 \square 5 \square 5) \square 5 = 4,$ $5 \square (5 \square 5) \square 5 = 5,$ $5 \square 5 \square (5 \square 5) \square 5 = 6.$

We can discover the rule found in the last digit number by multiplying the same number repeatedly. We can learn the rule, for example, through the calculations,

$7 = 7, \ 7 \times 7 = 49,$ $7 \times 7 \times 7 = 343,$ $7 \times 7 \times 7 \times 7 = 2401,$
$7 \times 7 \times 7 \times 7 \times 7 = 16807, \cdots.$

We can also find out some principles and laws on the basis of the regularities in the numbers produced by multiplying double digit or more digit numbers repeatedly. For instance,

$(1 \times 9) + 2 = 11, \ (12 \times 9) + 3 = 111, \ (123 \times 9) + 4 = 1111, \ (1234 \times 9) + 5 = 11111,$
$(12345 \times 9) + 6 = 111111, \cdots.$

$9 \times 9 = 81, \quad 99 \times 99 = 9801, \quad 999 \times 999 = 998001, \quad 9999 \times 9999 = 99980001,$
$99999 \times 99999 = 9999800001, \cdots.$

$101 \times 222 = 22422, \quad 101 \times 2222 = 224422, \quad 101 \times 333 = 33633,$
$101 \times 333 = 336633, \quad 101 \times 33333 = 3366633, \cdots.$

Table 2. Teaching-Learning Activities for Discovering Principles

Stage	Teaching & Learning Activities
Understanding the problem	Presentation of study questions and establishment of learning scenes Motivating students and helping them understand objectives
Anticipation	Devising a plan to solve the questions Presentation of anticipation or hypothesis
Verification	Verification Discovering principles and rules using calculators
Generalization	Checking the validity of the principles and rules Making statements and formulating them; attaching them to the existing knowledge
Application	Making use of the principles and rules using calculators Applying them to solving problems using calculators

These problems can help students understand principles or rules.

The teaching-learning model (see Table 2 above) shows how calculators can be used in the discovery of properties and principles.

3) Problem-Solving Application Patterns

To develop the problem-solving ability, strategies to discover important concepts and principles and solve problems need to be taught. For instance, if we shorten the time in calculating with figures written down on paper in solving problems by using the discovery of problem-solving pattern, the reconstruction of experience, the process of appropriate reasoning, the usage of given conditions, we can generalize the methods of solution and apply them to similar or application problems.

Problem 1. What will happen if a two-digit number is multiplied by 101? Why do you have such result?

$$101 \times 47 = (\quad), \qquad 101 \times 62 = (\quad), \qquad 101 \times (\quad) = (\quad),$$
$$101 \times 23 = (\quad), \qquad 101 \times (\quad) = (\quad), \qquad 101 \times (\quad) = (\quad).$$

And what number has to be multiplied to make three-digits of numbers repeat?

We can use calculators in calculating the areas of plane figures such as triangles, circles and the surface area and bulk of solid figures such as a rectangular parallelepiped, and getting averages.

Problem 2. You lent 530,000 won at an annual interest rate of 9% for one and a half years. How much money has to be given back to you in one year and six months?

Problem 3. What is the average of the following numbers?

   80   95   85   98   90   90   75   80   85   70

Problem 4. What are the base area, the side area, and the surface area of the cone with 2cm as the base area and 8cm as the edge length?

Problem 5. After measuring the diameters and circumferences of various objects, calculate to four decimals how many times the circumference is longer than diameter by using a calculator (see table 3).

Polya (1985) explains problem-solving by four stages;

   understanding the problem, devising a plan, carrying out the plan, and looking back.

Calculators can be used in carrying out the planning stage, thus allowing students to pay more attention to understanding the three other stages.

Table 3. Measuring the diameters and circumferences

Object	Diameter	Circumference	Circumference ÷ Diameter
Bottle	7cm	22cm	3.1428⋯
Can	8.5cm	26.7cm	3.1411⋯
Big tray	35cm	110cm	3.1428⋯

The teaching and learning model (see Table 4 below) shows how calculators can be used for such purpose.

Table 4. Teaching-Learning Activities in Problem-Solving Model

Stage	Teaching & Learning Activities
Understanding the problem	Understanding the intent of the problem
Devising a plan	Confirming the concept stated in the question Collecting data needed to solve the problem Anticipating and planning to solve the problem
Carrying out the plan	Carrying out the plan to solve the problem using a calculator
Looking back	Looking back at the solving process Reconfirming the concepts, principles and rules using a calculator

4. AN EXAMPLE OF TEACHING & LEARNING ACTIVITIES IN PROBLEM-SOLVING PROCESSES

1) Unit 6-1-11. Different kinds of problems (2)

2) The Lesson Plan

Subject	Ratio graph (7th lesson out of 8 lessons)
Objective	Students will be able to analyze statistical data found in daily life. Student will be able to transform the data into a ratio graph format.
Learning Content	Pattern of problem discovery strategies
Organization of Learning Groups	After teaching the whole class, individual teaching follows

Learning Activities	Collecting data → Classifying data → Intuitive analysis of data → Interpreting data → Adjusting	
Materials Learning Materials	Mathematics textbook, training book, magazines, various statistic materials, electronic calculator	
Aids Materials	TP materials, image processor, presentation materials	

3) Teaching-Learning Activities

Learning Content	Learning Activities	
	Presenting, Explaining and Guiding Learning Tasks	Expected Thoughts and Activities of Students
Understanding Learning Tasks	Looking at the presentation of ratio graph - Looking ⇑ Talking about the content - Taking about the experience of using the ratio graph or the place where the ratio graph was used Find out favorite sports (teachers, talents, singers) and have them published in school newspaper. How can we present them? - Pictures, Sentences, Tables, Ratio, Graphs	Talking about the content of presentation Taking about one's own experience of using the ratio graph → Why was the ratio graph used? Talk about favorite sports (fruits, talents, singers.) Discuss ways of publishing in school newspaper
Understanding Problems and Devising Lesson Plan	Let's transform the following table into a ratio graph and publish it in school paper. * Future Career (total 40 person) doctor (2), entertainer (5), singer (6), athlete (4), teacher (15), nurse (8).	Understanding the learning task ↓ Searching for ways to solve it ↓ Devising a plan
Reading and analyzing data	Presenting questions about the data What is the table about? How many students want to be an athlete? How many students want to be an entertainer? The total number of students?	

Displaying data into graph *Remark: Using Calculator	Let's transform the data into a ratio graph * Grouping according to the graph (see Table 5 below) Calculating the size occupying each part Band graph : (the whole graph length) × (numbers of part/numbers of total) Circle graph : 360° × (numbers of part/numbers of total) Let's compare each group's ratio graph.	Calculating the size of each graph Band graph: the length of each part Circle graph: the size of central angle Quadrangle graph: the number of quadrangle Picture: the size of each picture Drawing graph of each group
Comparing the Properties of the Ratio Graph	Let's compare the characteristics of ratio graphs represented.	Band graph: easy to represent percentage, but difficult to see Circle graph: easy to compare each part, but difficult to calculate the central angle Quadrangle graph: easy to draw, but difficult to show low-ratio article
Applying to Reality *Remark: Using Calculator	Let's compare and analyze different kinds of ratio graphs. Let's complete a ratio graph, which has information missing. (The Whole Class Group Learning) Let's get to know how the Korean industrial population has changed on the basis of a band graph.	Presenting the name of the ratio graph, interpreting each part, comparing with the whole, and understanding the purpose Completing the given data How has the agricultural and fisheries population changed? Is there any industry whose ratio continues to increase?
Consolidation and Wrap-up	How do you draw the ratio graph? Provide guidance to the next class.	Present each part as a part of the whole.

Table 5. Grouping according to the graph

Band graph	Circle graph	Quadrangle graph	Picture	Others
Group 1	Group 2	Group 3	Group 4	Group 5

5. CONCLUDING REMARKS

Research about the educational uses of calculators in Korea dates back to early 1990's. In secondary schools, calculators are in particularly active use in teaching algebra, equations and inequalities, functions, statistics, and geometry. Their use in elementary schools, however, is minimal in Korea. This presentation represents an attempt to suggest teaching and learning models in which calculators can be put to use effectively to teach mathematics in elementary schools. The ideas contained in this presentation are expected to give useful guidelines about when to use calculators.

When appropriately utilized, calculators will affect positively students' interest and confidence in learning, thus enhancing their ego. It has to be borne in mind, however, that calculators are nothing more than instructional tools in the mathematics learning and teaching process. In order to use them effectively, it is essential that teachers plan well in advance and supplement the possible shortcomings of calculators.

REFERENCES

Ahn, Byoung-Gon et al. (2000): A Design for Instructional Model to Use Calculators in Elementary School Mathematics. *Journal of Elementary Mathematics Education in Korea* 4, 1–19.

Ahn, Byoung-Gon & Kim, Yong-Tae (1998): A Study of Ways Using Calculators in Elementary Mathematics Textbook. *Journal of Elementary Mathematics Education in Korea* 2, 23–40.

Gwangju National University of Education Elementary School (1999): *Learner-centered Learning* (Korean). Seoul: Educational Science Publ.

Kang, Ok-Ki (1998): Study on the Development of a Model for Teaching and Learning Mathematics Using Graphic Calculators. *Journal of the Korea Society of Educational Studies in Mathematics* 8(2), 453–474

Kim, Jin-Soo & Jung, Chang-Hyun (1995): A Study of Using Calculators in Mathematics Education in Elementary Schools. *J. Korea Soc. Math. Educ. Ser. E Proc. Math. Educ.* 3, 125–140.

Koh, Sang Sook (1999): The Effect of a Graphing Calculator in Trigonometry: Analysis of Thinking Process by Qualitative Research Method. *Journal of the Korea of Educational Studies in Mathematics School Mathematics* 1(2), 483–512

Koo, Gwang-Jo et al. (1992): *Curriculum and Evaluation Standards for School Mathematics*. Seoul: Kyungmoonsa.

Lew, Hee-Chan (1991): *Report about Content Revision of Mathematics Curriculum. Chungram athematics Education (Center of Mathematics Study of Korea National University of Educa-*

tion) **2**, 59–60.

Ministry of Education (1994): *Elementary School Curriculum (1)*. Seoul: Ministry of Education.

_____ (1999): *Elementary School Curriculum (IV)*. Seoul: Ministry of Education.

Na, Gwi-Soo (1999): An Instruction of the Underachieved Students of using Graphic Calculators. *Journal of the Korea Society of Educational Studies in Mathematics* **11(1)**, 167–181

Nam, Seung-In & Kim, Ok-Kyeong (1998): A Study on the Use Calculators in Elementary Mathematics. *Journal of the Korea Society of Educational Studies in Mathematics* **8(1)**, 251–268.

Park, Kyo-Sik (1998): Study on How to Use Calculators in Elementary Mathematics Education in Korea. *Journal of the Korea Society of Educational Studies in Mathematics* **8(1)**, 237–249.

_____ (1997): A Study on the Process of Using Calculators in Elementary Mathematics Education in Korea. *Journal of the Korea Society of Educational Studies in Mathematics* **7(2)**, 173–188.

Polya, G. (1985): *How to solve it — a new aspect of mathematical method*. Princeton, NJ: Princeton University Press.   MATHDI **1990j**.01910

Shimizu, Shizumi (清水靜海) (1992): 改正 小學校 教育課程 講座 算數 (Japanese). Tokyo: ぎょうせい

Whang, Woo-Hyung (1994): Using Calculators in Mathematics Education (Korean). *Newsletter of the Korean Mathematical Society* **39**, 22–23.

_____ (1997): Graphing Calculators in Secondary Mathematics. *Journal of the Korea Society of Educational Studies in Mathematics* **7(2)**, 215–254.